

Signals and Circuits

ENGR 35500

Diodes

Chapter 16: From 16-1 to 16-4 (pp. 720-744)

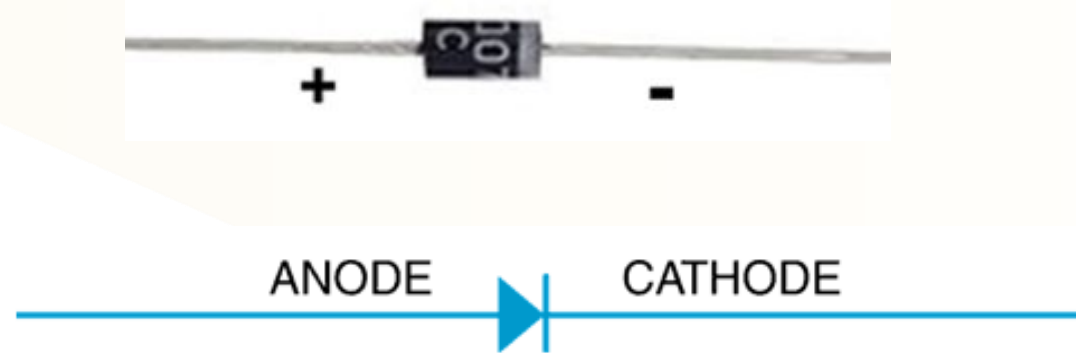
Text books:

Floyd, T. L., and Buchla, D. M., *Electronics Fundamentals: Circuits, Devices & Applications*, 8th Edition, Pearson, 2009.



Diode

a semiconductor device with two terminals, typically allowing the flow of current in one direction only.



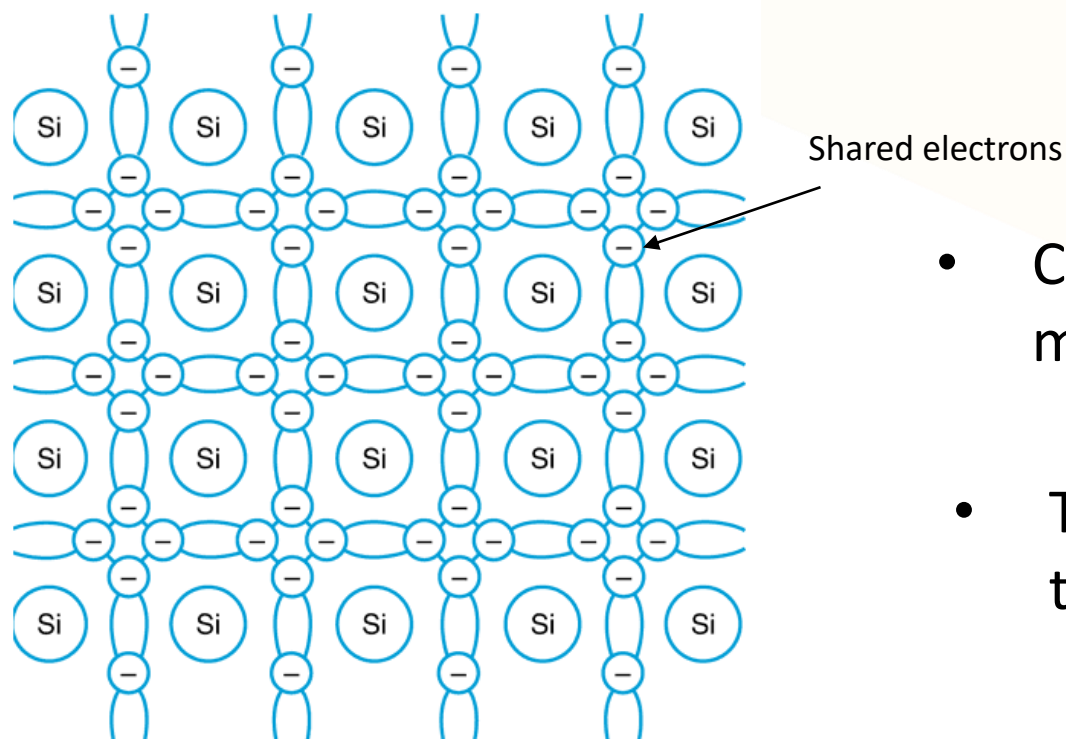
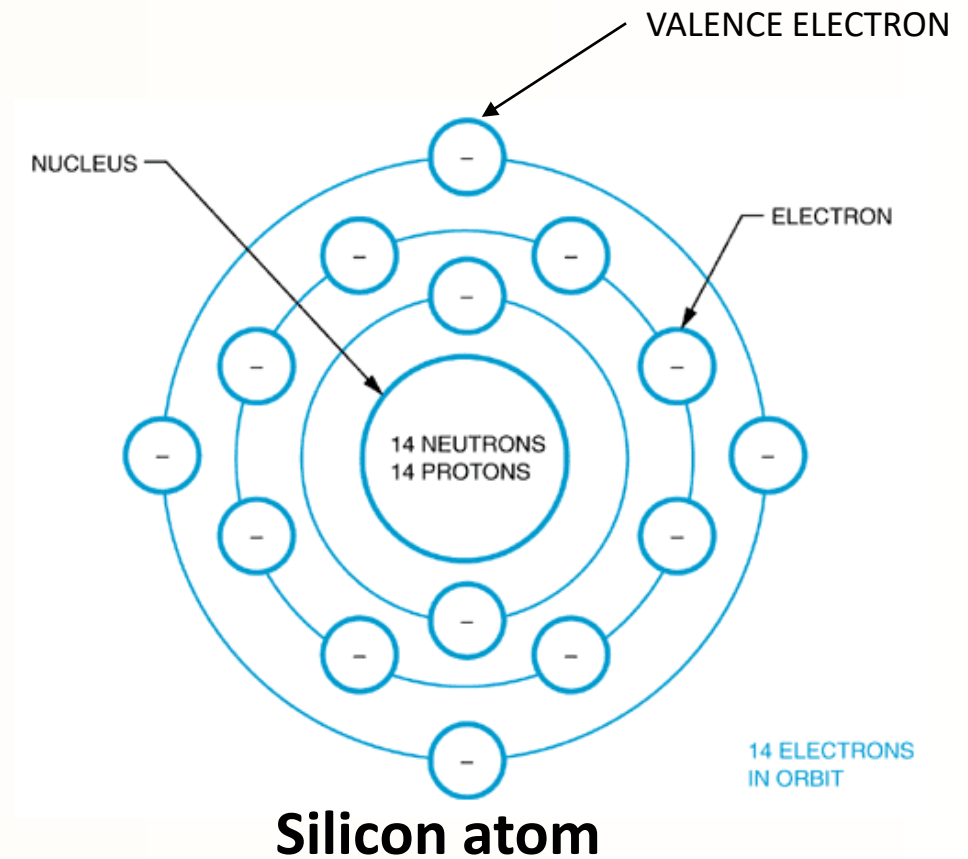
A junction diode is created by joining N- and P-type semiconductive materials together.

Semiconductive materials

- Characteristics of semiconductive materials
 - Electrical characteristics fall between those of insulators and conductors.
 - They are not ohmic materials
 - They have negative temperature coefficients.
- There are three pure semiconductor elements:
 - Carbon (C).
 - Germanium (Ge).
 - Silicon (Si).

Semiconductive materials

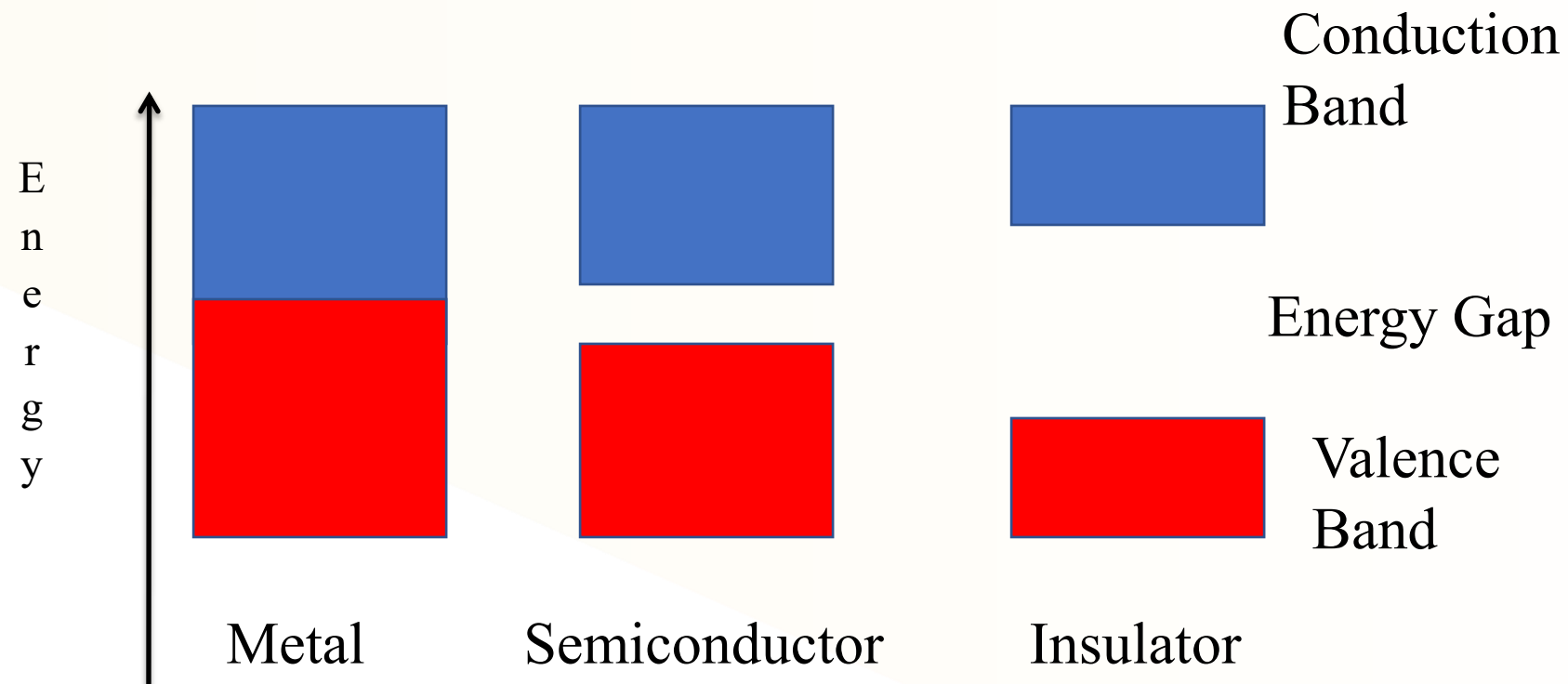
- Valence electrons is in the outer (valence) Shell.
- There are usually four valence electrons in the atom of semiconductive materials



Silicon bonding diagram

- Certain atoms combine to form a solid materials in a fixed pattern, called crystal.
- The atoms within the crystal are held together by covalent bonds.

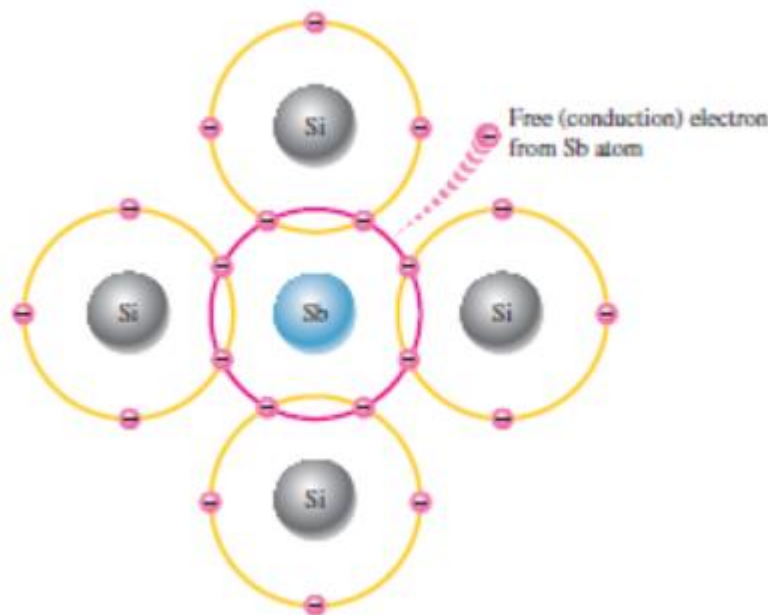
Electronic band structure



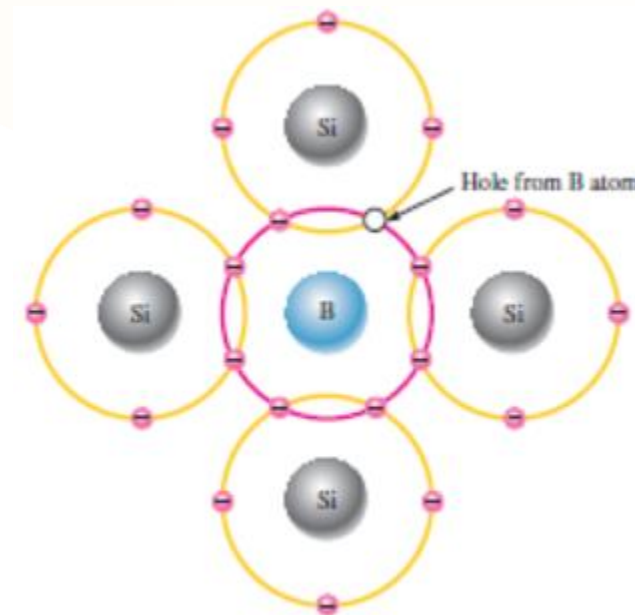
Doping

➤ To increase conductivity of semiconductors, a process called doping is used.

- Doping is the process of adding impurities to a semiconductor material.
 - Pentavalent is made of atoms with five valence electrons.
 - Arsenic (As).
 - Antimony (Sb).
 - Trivalent is made of atoms with three valence electrons.
 - Indium (In).
 - Gallium (Ga).
 - Boron (B)



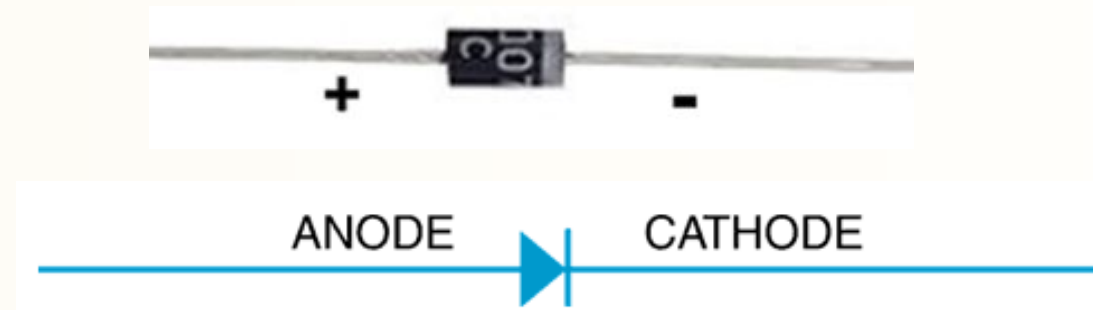
N-type semiconductor



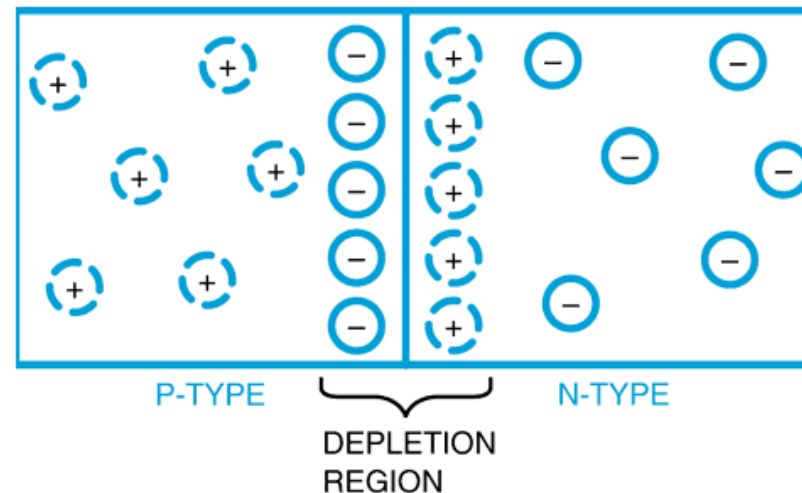
P-type semiconductor

Diode

a semiconductor device with two terminals, typically allowing the flow of current in one direction only.



A junction diode is created by joining N- and P-type semiconductive materials together.

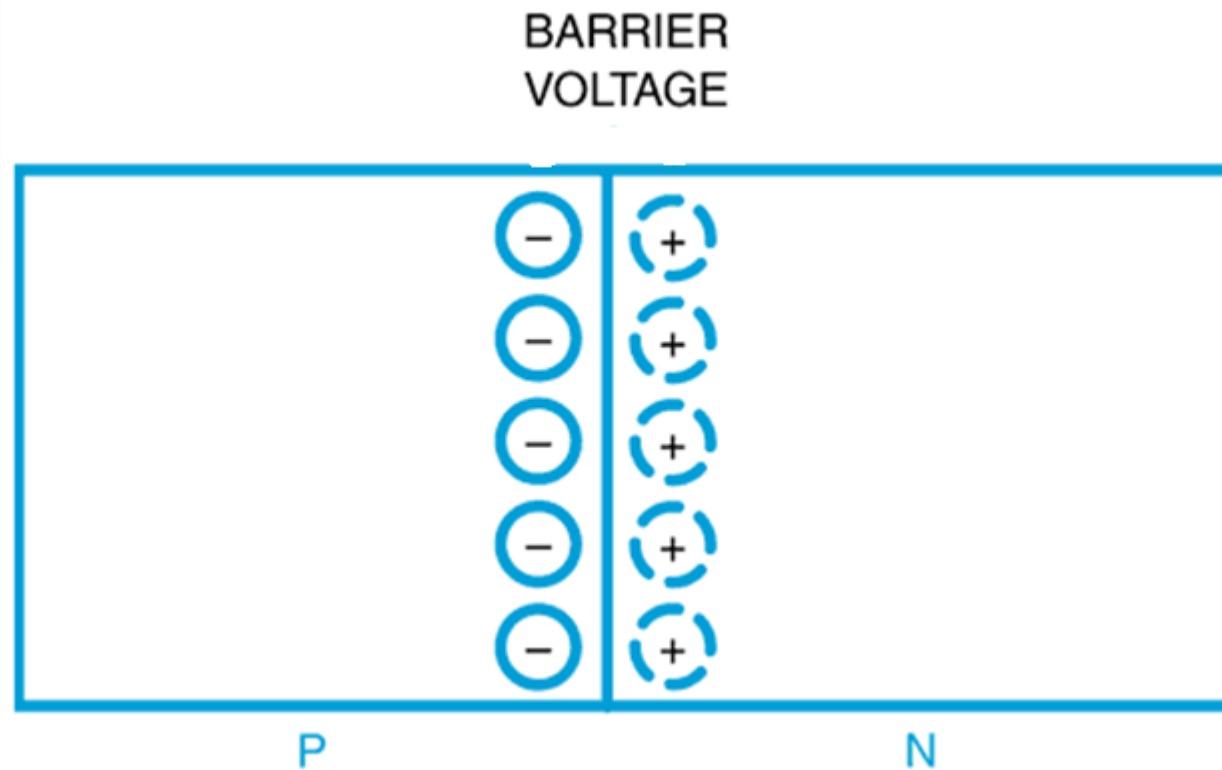


The depletion region is the area near the junction where electrons and holes are depleted; it extends only a short distance on either side of the junction.

Diode

➤ The barrier voltage (Barrier potential)

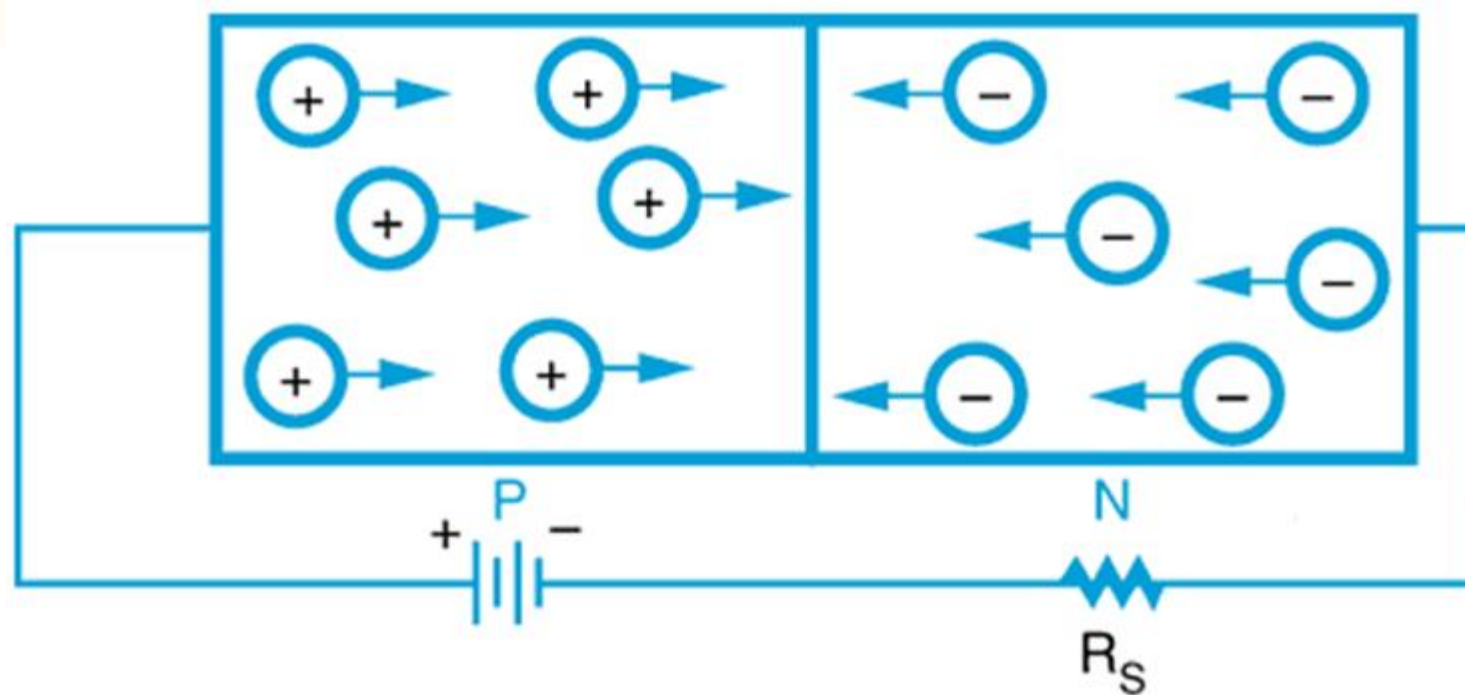
- Opposite charges that build up on each side of the junction.



Diode

➤ Bias voltage

- In electronics, bias refers to use a dc voltage to establish certain operation conditions for an electronic devices;
- When a voltage is applied to a diode it is referred to as a bias voltage.



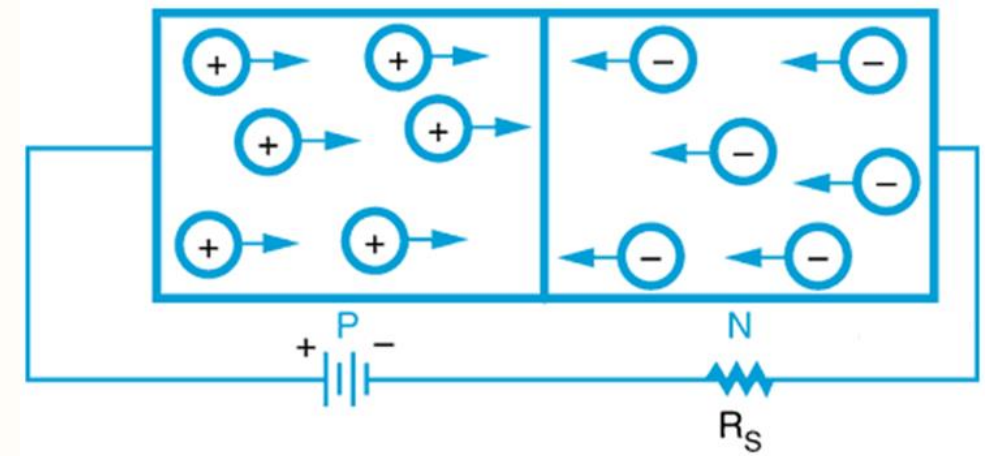
Diode

➤ Forward bias

- When the electrons flow from the N-type to the P-type material, the diode has a forward bias.
 - Germanium diodes require a minimum bias flow of .3 volt.
 - Silicon diodes require a minimum bias flow of .7 volt.

➤ Forward voltage drop

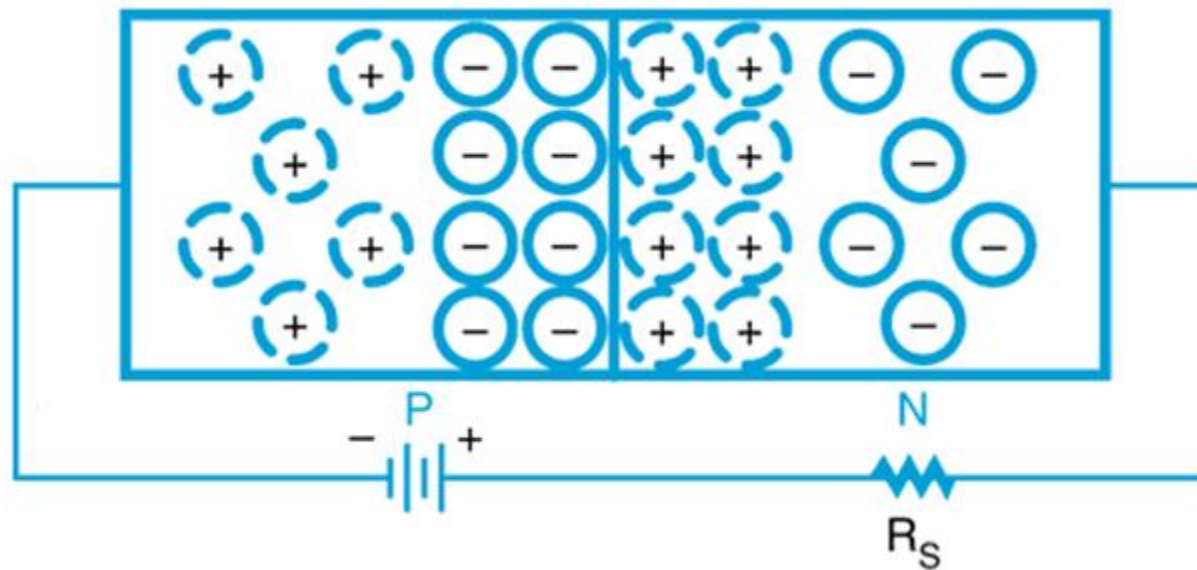
- Once a diode starts conducting, a voltage drop known as a forward voltage drop occurs.
 - Voltage drop for germanium = .3 volt.
 - Voltage drop for silicon = .7 volt.



Diode

➤ Reverse bias

- A diode where the terminals are reversed.
- The diode does not conduct.
- Only a small leakage current flows.



Diode

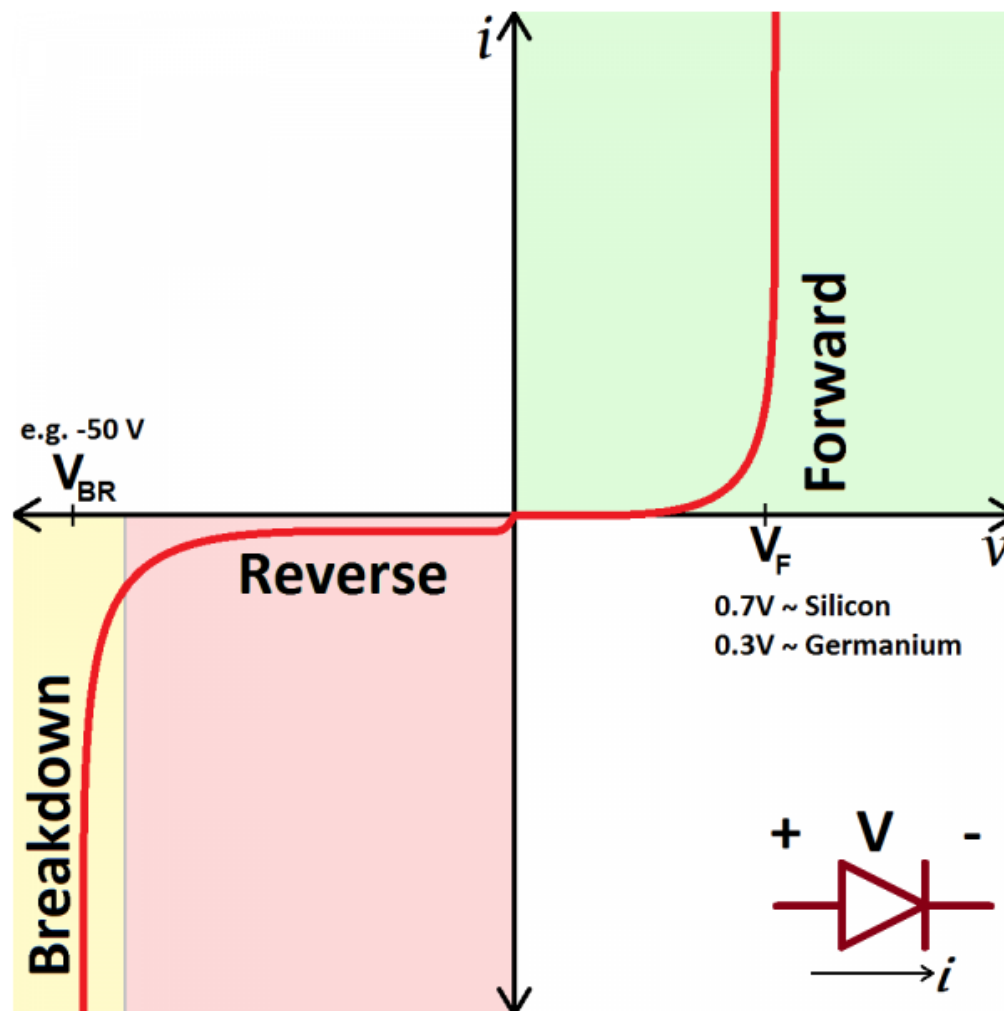
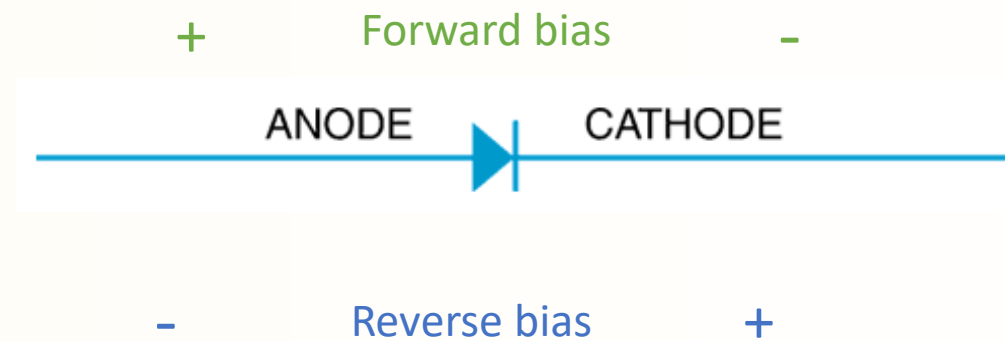
➤ Diode characteristics

- Can be damaged by excessive heat.
- Can be damaged by excessive reverse voltage.
- At room temperature, reverse current is small.



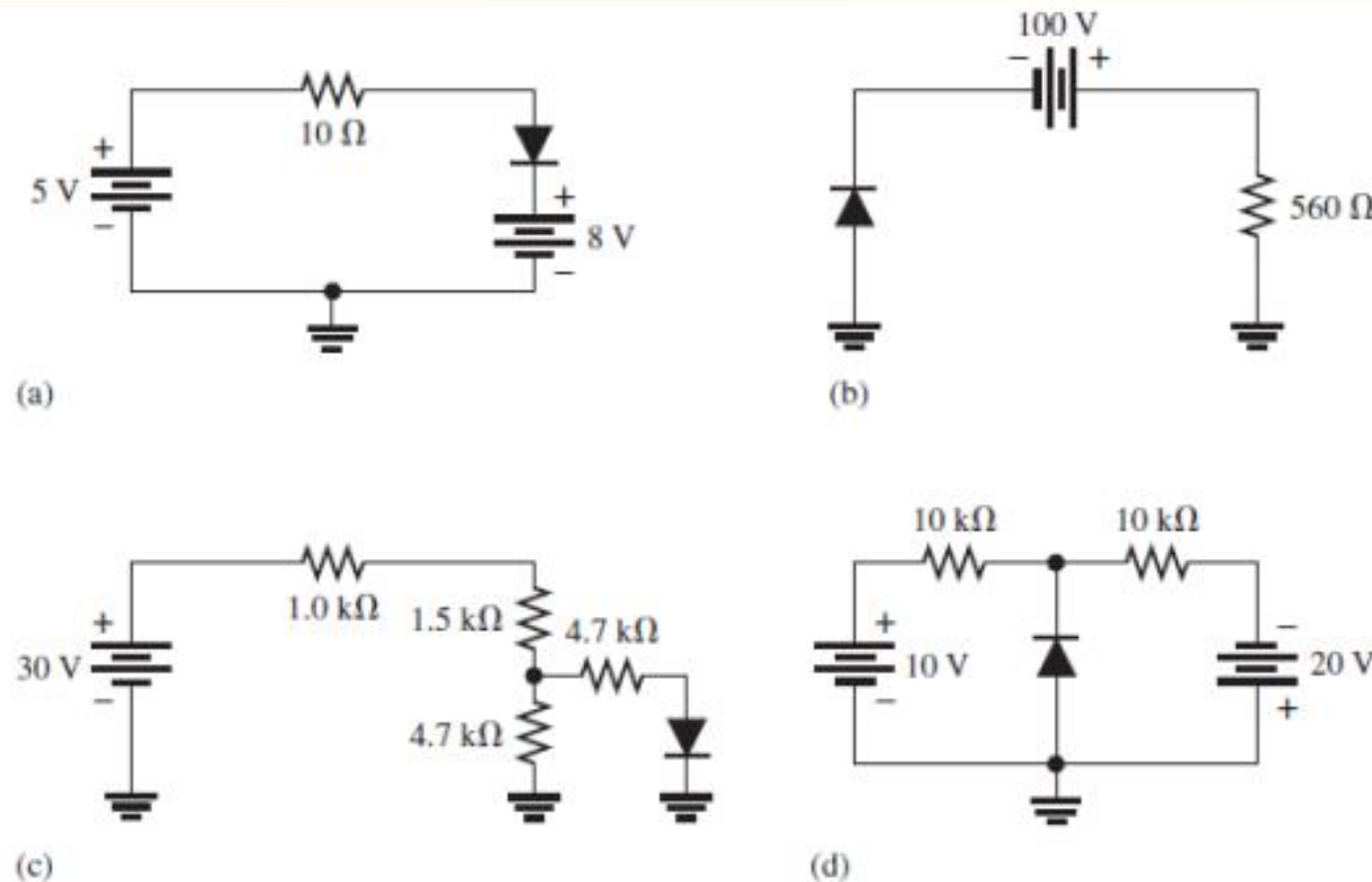
Diode

Diode characteristics



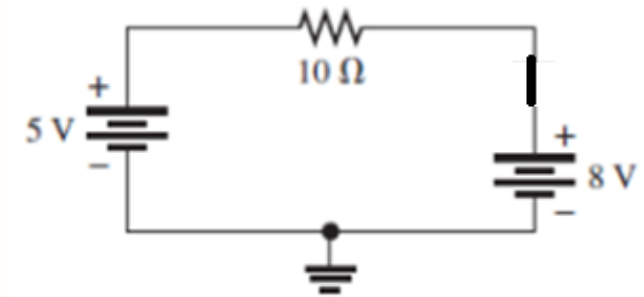
Diode

E.g. Determine the voltage across each diode.



Step 1: Make assumption

Assume the diode is on forward bias, then there is a short on the diode part



Then the current

$$I = \frac{8 - 5}{10} = 0.3A$$

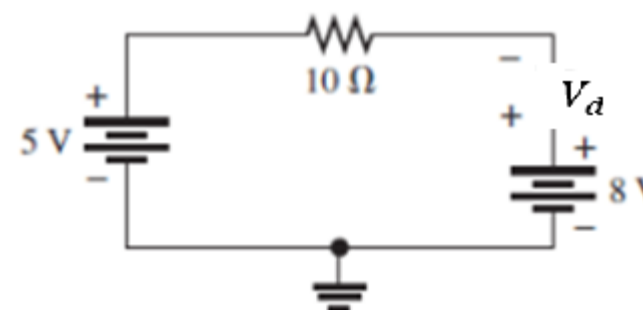
The assumed direction is counterclockwise

Step 2: Compare with the assumption

This is not consistent with the assumption, so the assumption is wrong.

Thus, the diode is on reverse bias.

Step 3: Calculate on the correct case



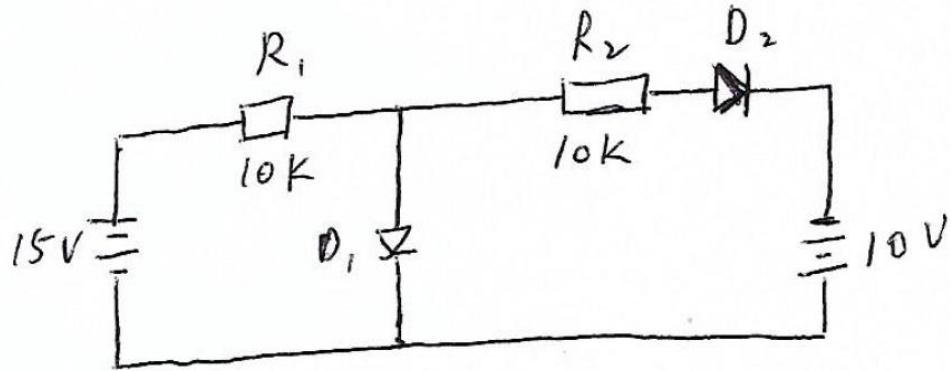
$$\text{KVL} \quad -5 - V_d + 8 = 0$$

$$V_d = 3V$$

Diode

E.g.

Determine the voltage across each diode.

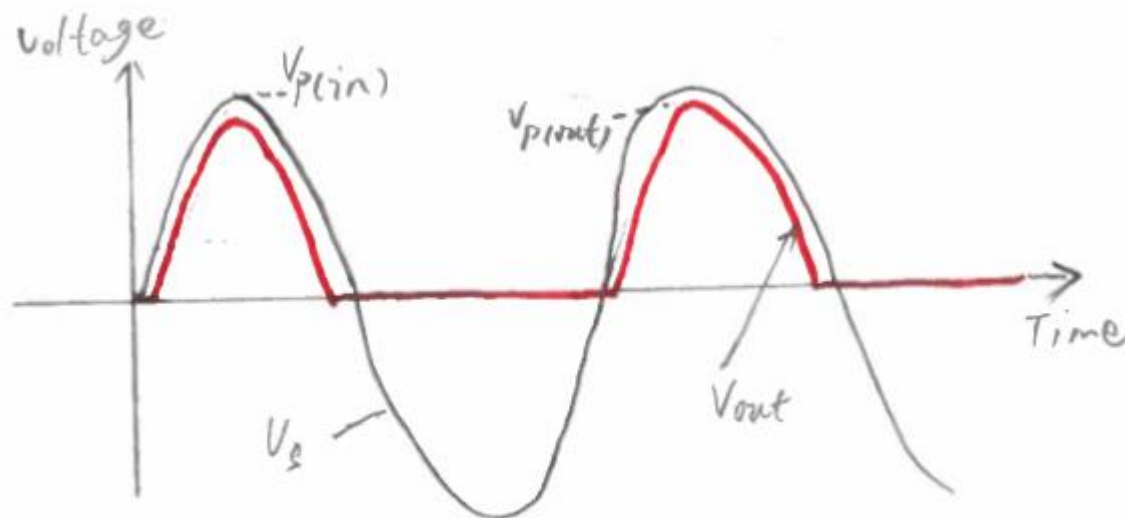
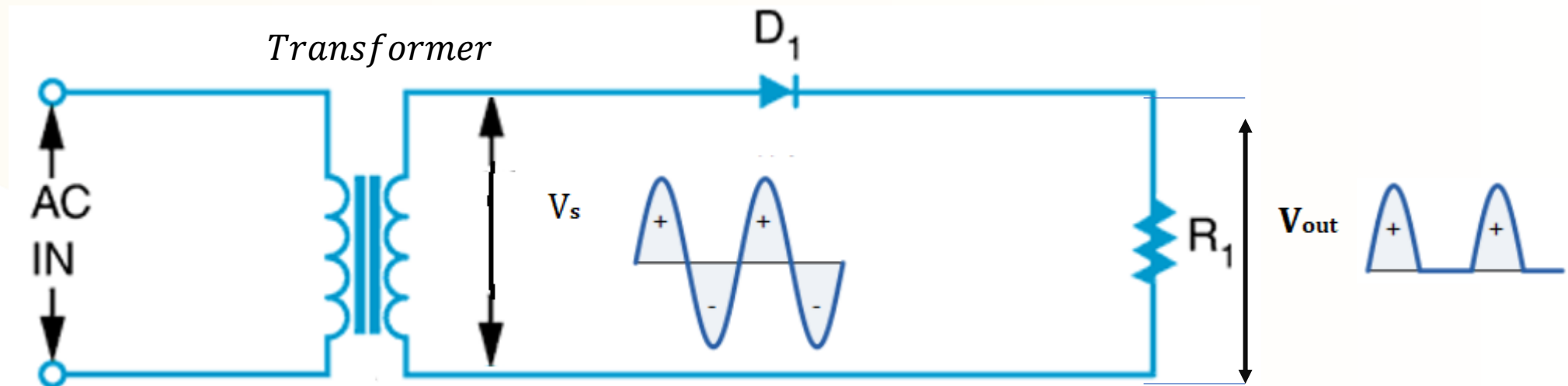


Rectifier Circuits

- The heart of the power supply.
- Converts incoming AC voltage to a DC voltage.
- Three basic types of rectifier circuits:
 - Half-wave rectifiers.
 - Full-wave rectifiers.
 - Bridge rectifiers.

Half-wave rectifiers

- Operates only during one half of the input cycle.
- Frequency is the same as the input frequency.

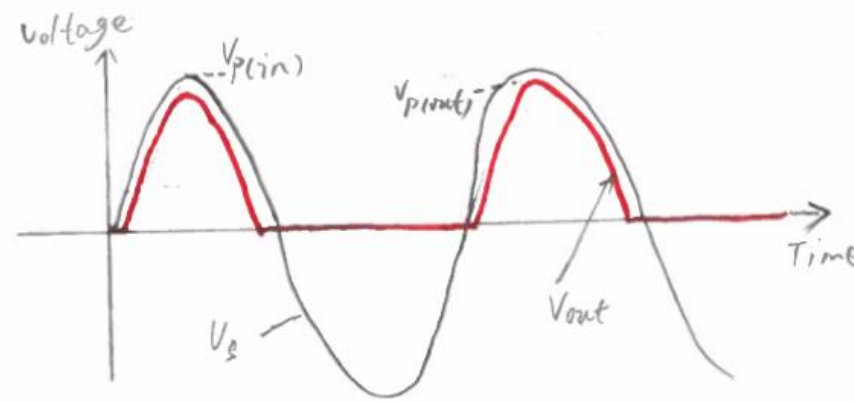


$$V_{avg} = \frac{V_{p(out)}}{\pi}$$

$$V_{p(out)} = V_{p(in)} - 0.7V$$

Half-wave rectifiers

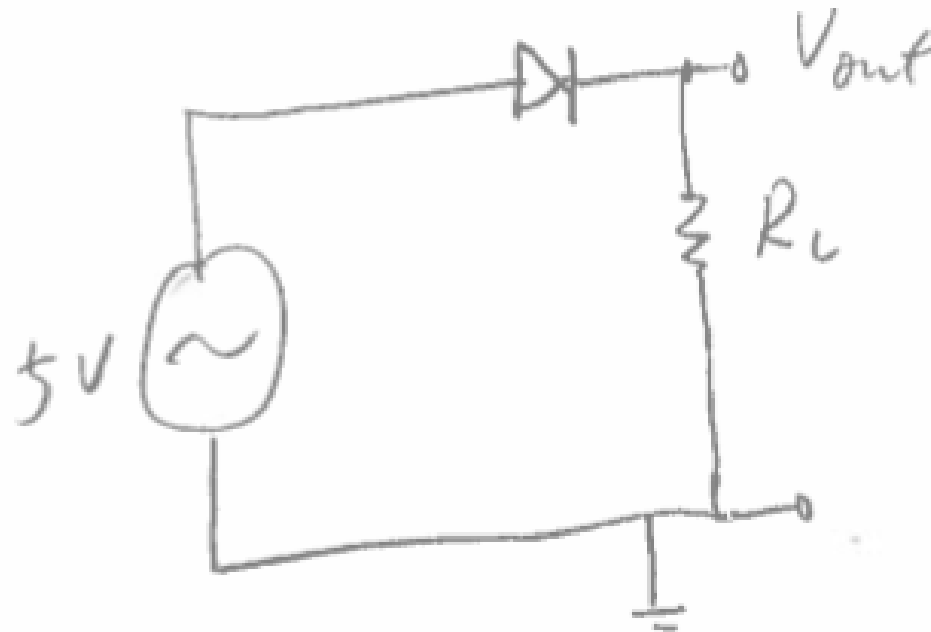
Note:



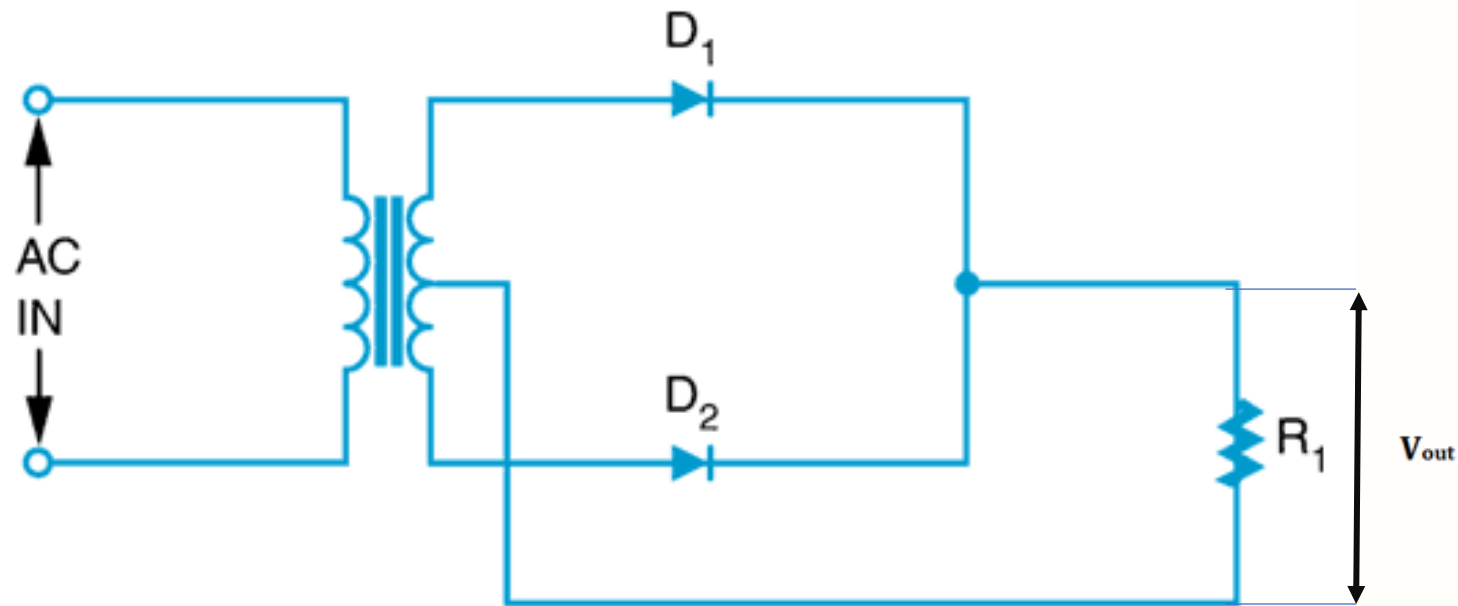
$$V_{avg} = \frac{V_{p(out)}}{\pi}$$

$$V_{p(out)} = V_{p(in)} - 0.7V$$

Determine the peak output voltage and the average value of the output voltage of the rectifier in the figure below for the indicated input voltage.

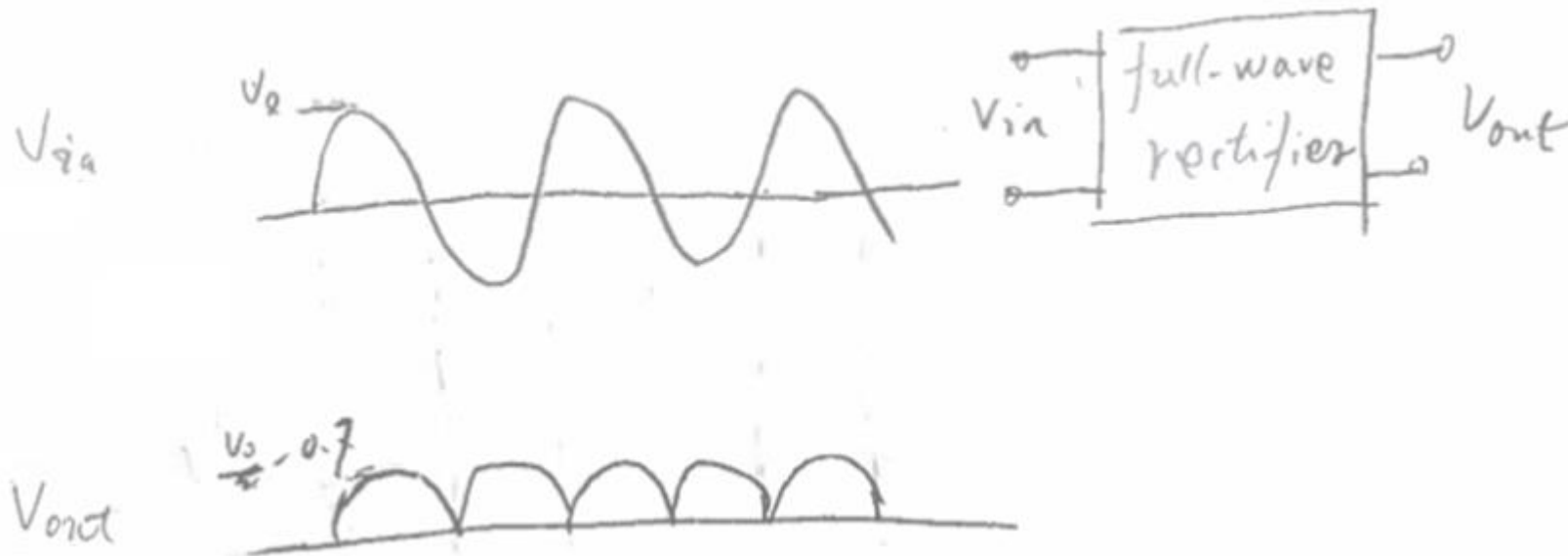


Full-wave rectifiers

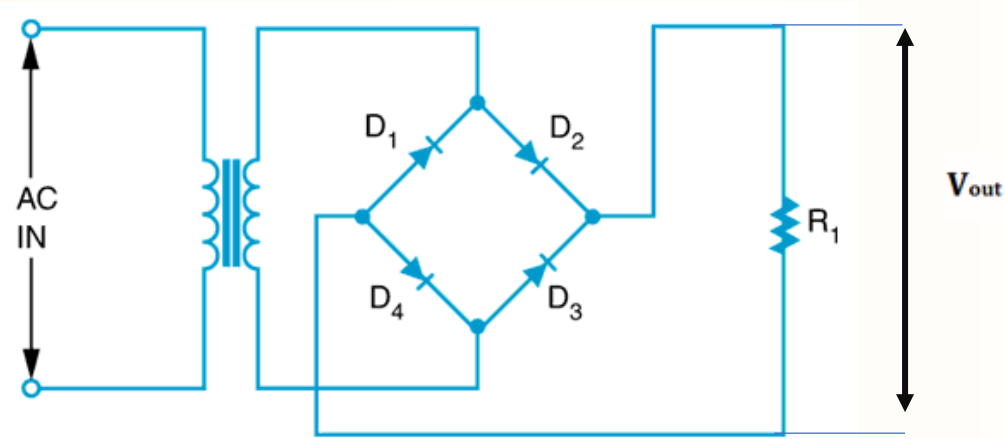


$$V_{avg} = \frac{2V_{p(out)}}{\pi}$$

$$V_{p(out)} = \frac{V_{p(in)}}{2} - 0.7V$$

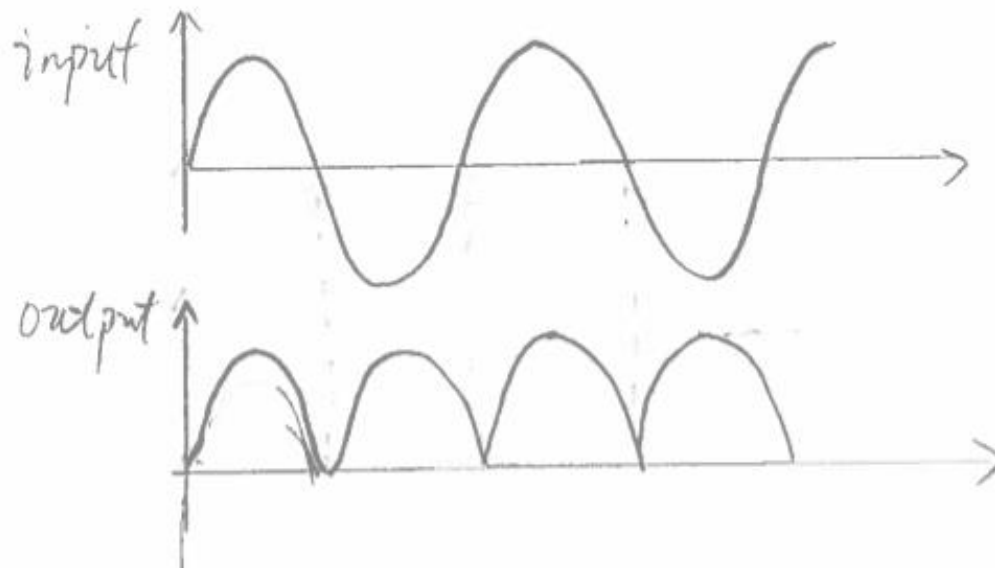


Full-wave bridge rectifier

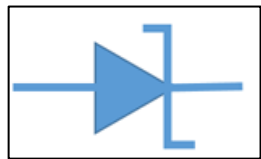
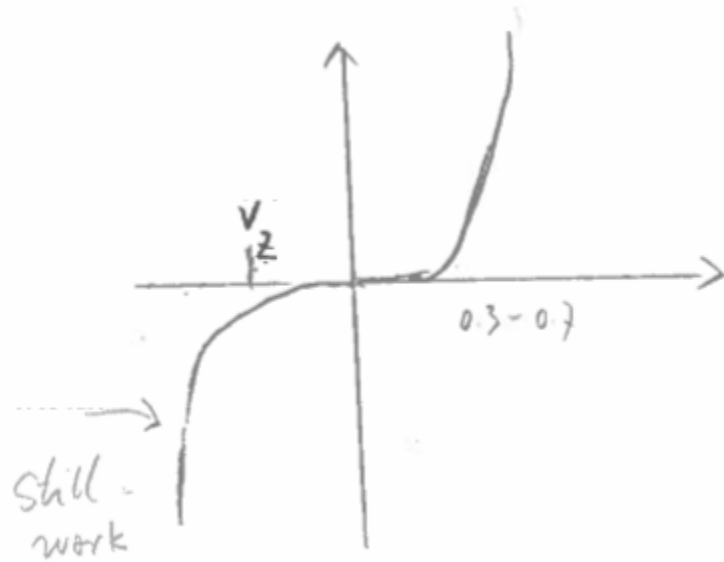


$$V_{avg} = \frac{2V_{p(out)}}{\pi}$$

$$V_{p(out)} = V_{p(in)} - 0.7 \times 2V$$



Special-purpose diodes



Zener diode



The Light-Emitting Diode (LED)